

CALWATER

*A Field Experiment Addressing
Key Uncertainties in Climate Projections
of Water Resources for California*

Dr. F. Martin Ralph

NOAA/OAR/ Earth System Research Laboratory

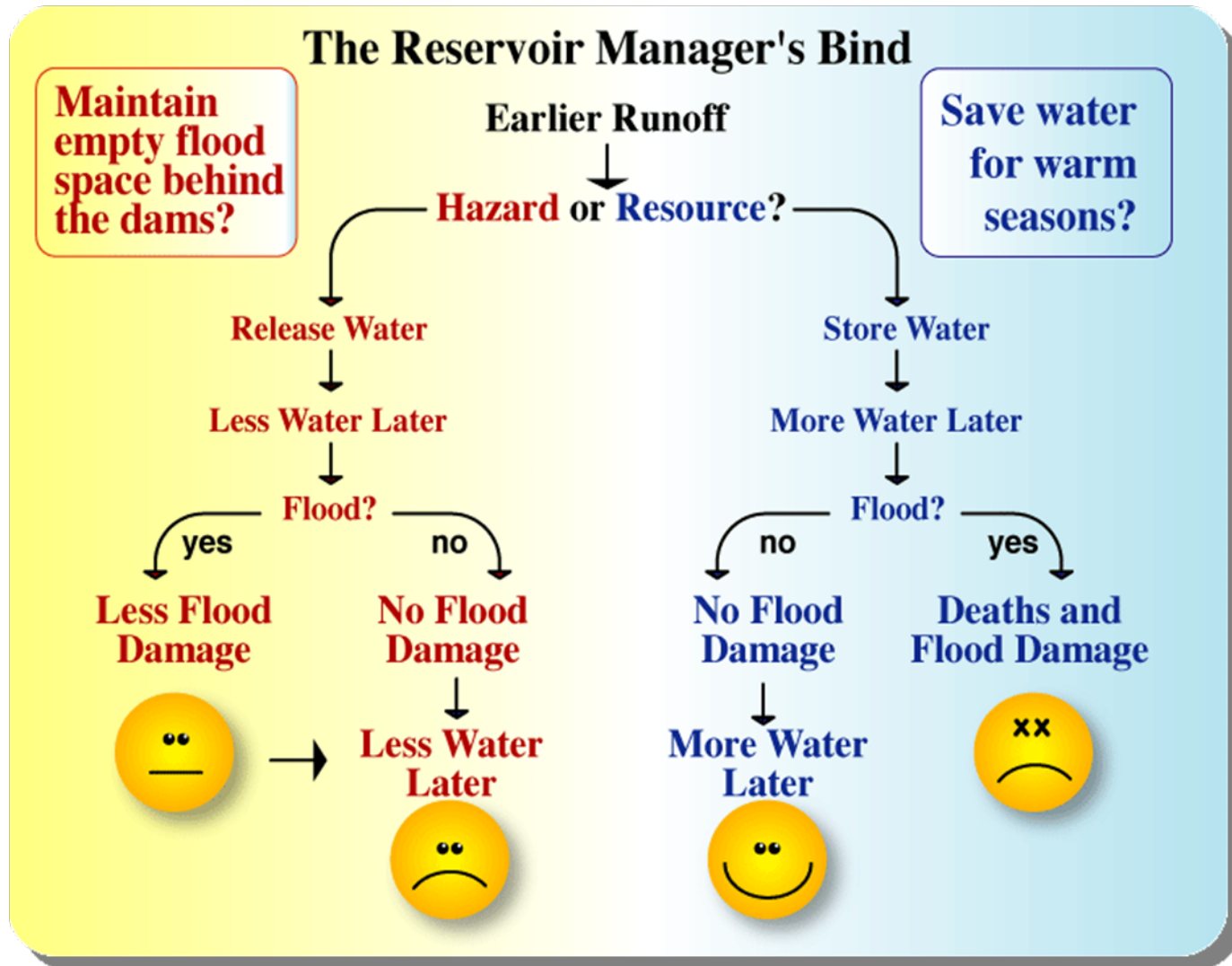
9 September 2008

California Energy Commission (CEC) Climate Change Conference
Sacramento, California

Motivation

- Snowmelt maximum is occurring earlier in the Spring
- Extreme rainfall events are projected to increase
- Reduced snow pack and water supply are projected
 - Warming reduces snowpack
 - Anthropogenic aerosol loading could reduce mountain precipitation
 - Deposition of dark aerosols onto snow pack changes melt rate
- Increasing transport of aerosols from Asian desertification and industrialization is expected
- Balancing water supply, flood control and many other uses will become increasingly difficult

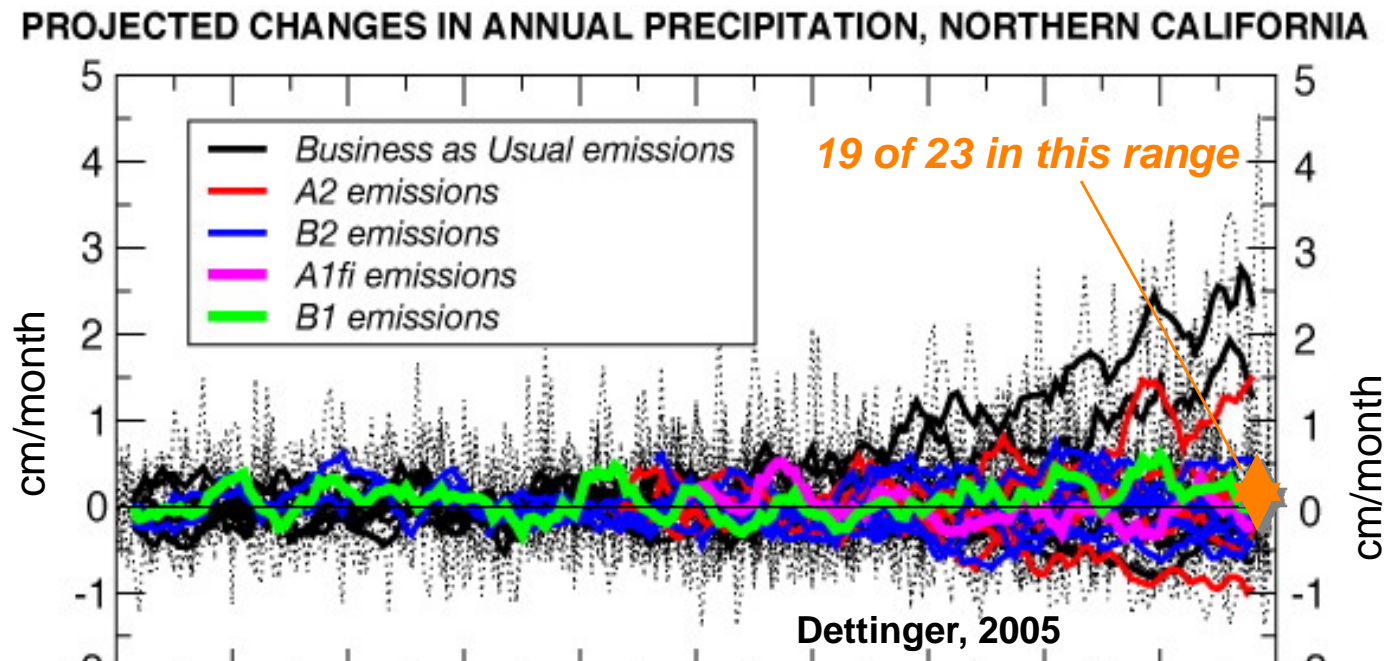
Climate change may put some water managers in a real bind!



--> Storage & transferability of water supplies will thus be at a premium.

Projected trends:

Precipitation



Most climate projections fall within a fairly narrow range of precipitation changes in much of the US. In Northern California, "small change" is most common projection.

4E - However, as with Arctic Pack Ice projections from IPCC, it is unclear that the current models capture the full range of uncertainty in annual precipitation and even with no change in
3C annual totals, the extreme events (storms/droughts) are expected to increase

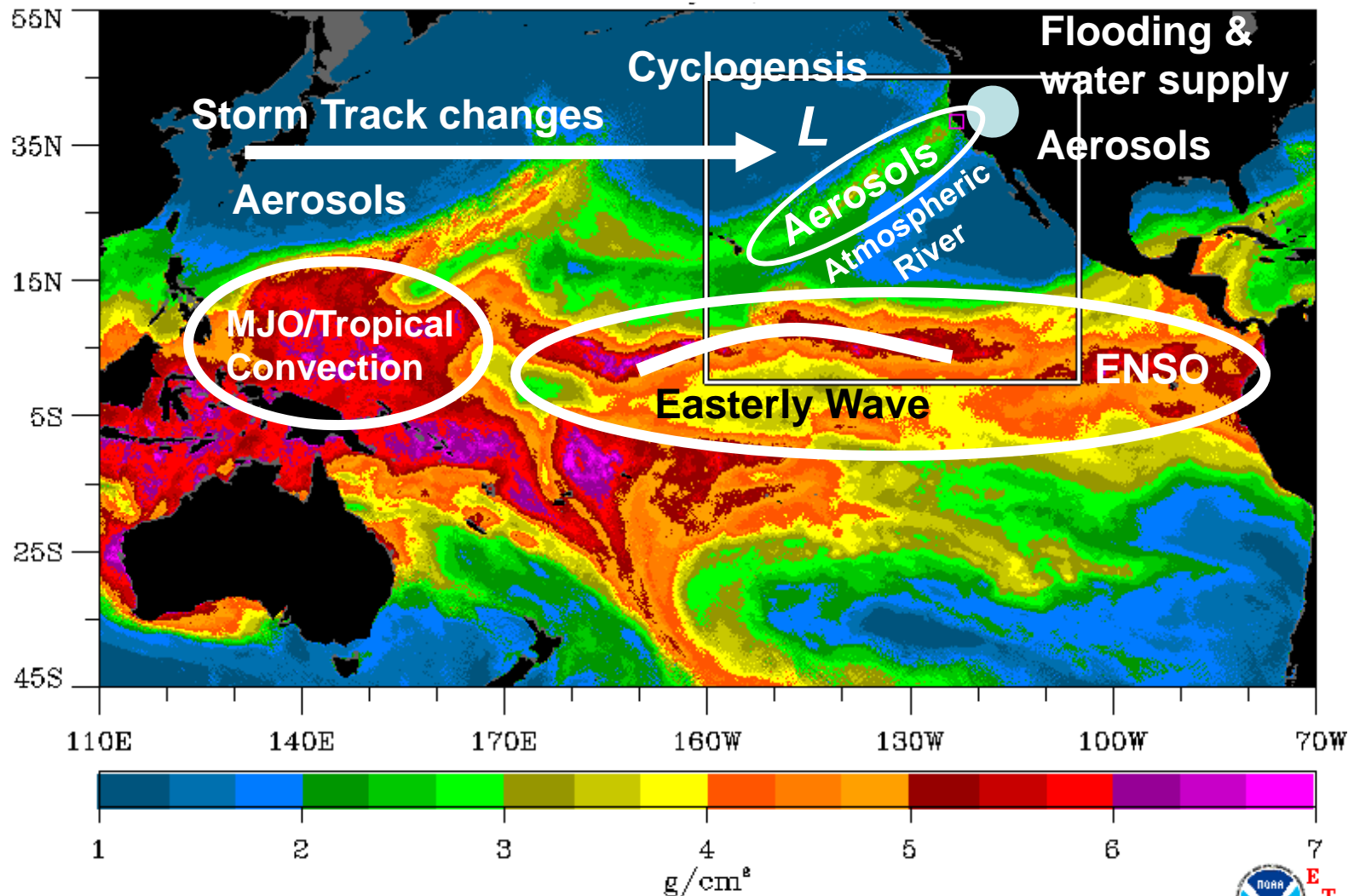
Motivation

- Consideration is being given to building new reservoirs, at great expense
- Science needs to provide sound assessments regarding the future of precipitation, snowpack and runoff for both water supply and flood control

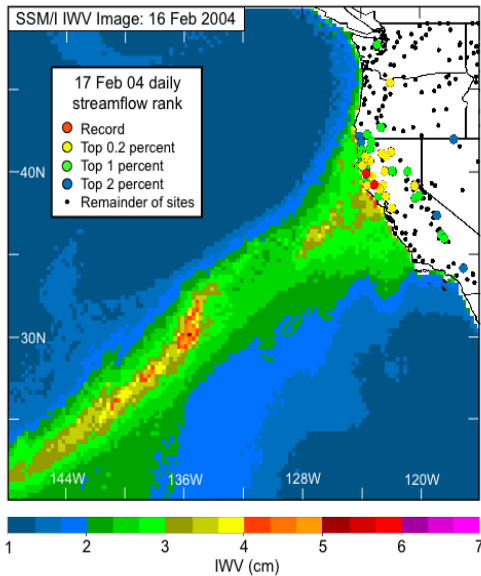
Broad Scientific Uncertainties Addressed by CalWater

- How do anthropogenic aerosols impact precipitation efficiency and snow melt?
- Will atmospheric river intensities and/or frequency of occurrence change, leading to changes in water supply and extreme storms?

Key Phenomena Affecting California Water Supply/Flooding



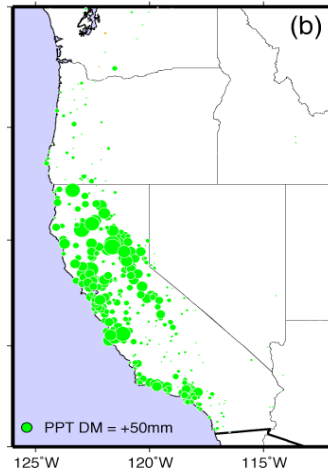
THE storms to worry about re: floods... **Atmospheric Rivers!**



- All 7 major floods of Russian River since 1997 have been fed by atmospheric rivers
- The 9 largest winter floods of Carson River since 1950 have been atmospheric rivers (i.e., pineapple expresses)

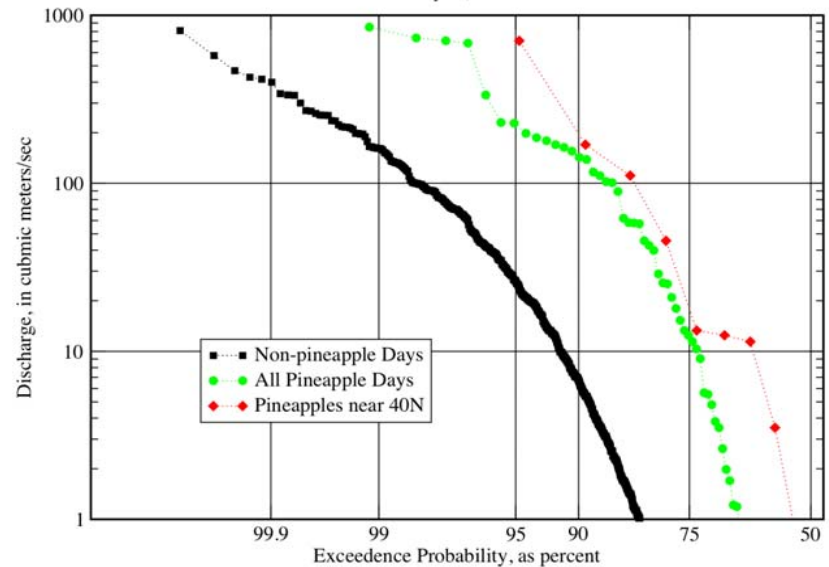
e.g., Ralph et al, GRL, 2006; Neiman et al, 2008

Stations with Mean Precip > +2 mm on Russian River flood dates



Corresponding precip patterns tend to be restricted mostly to Pacific coast states

DECEMBER-FEBRUARY DAILY DISCHARGE-CHANGE DISTRIBUTIONS
Blue Canyon, 1949-1999

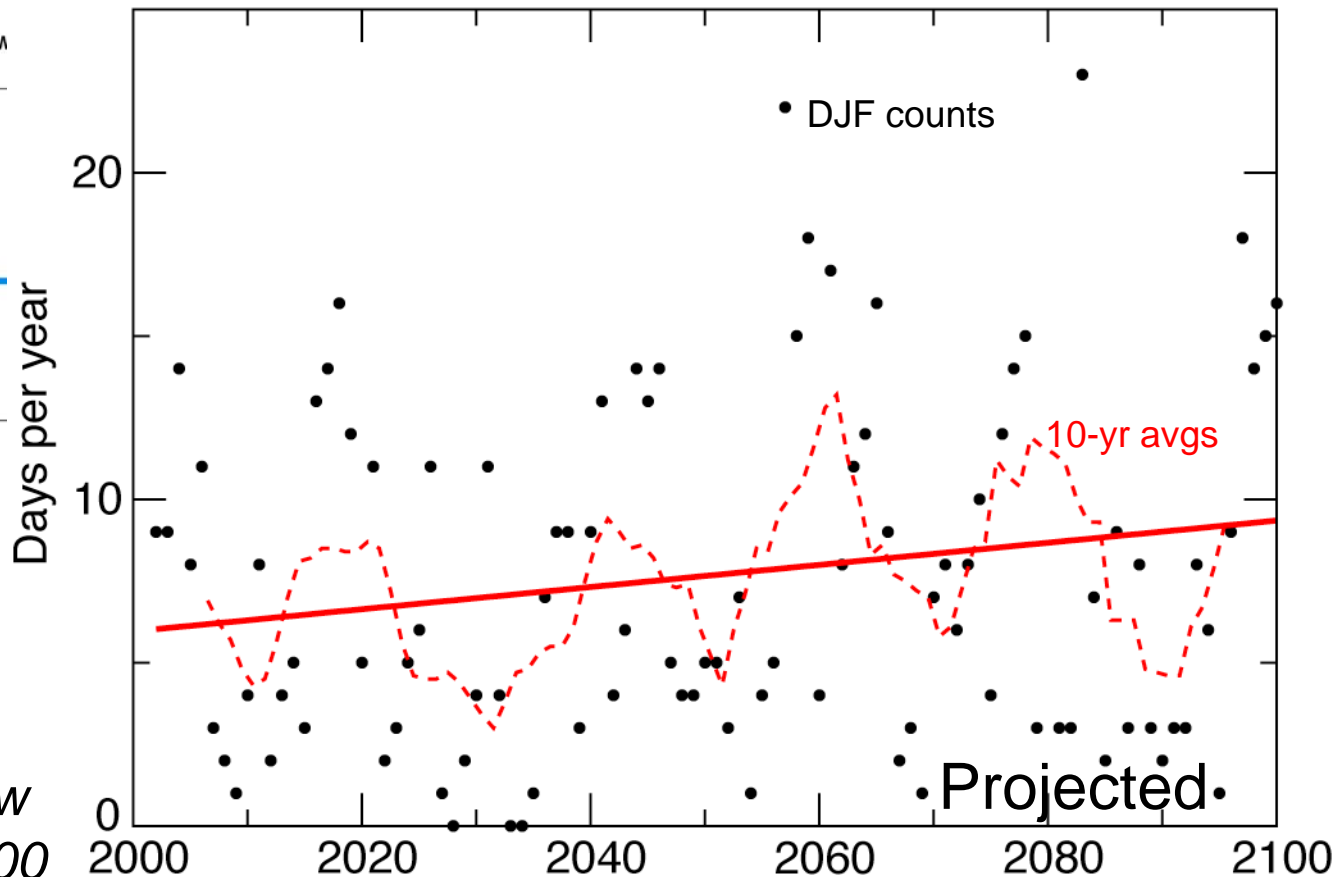
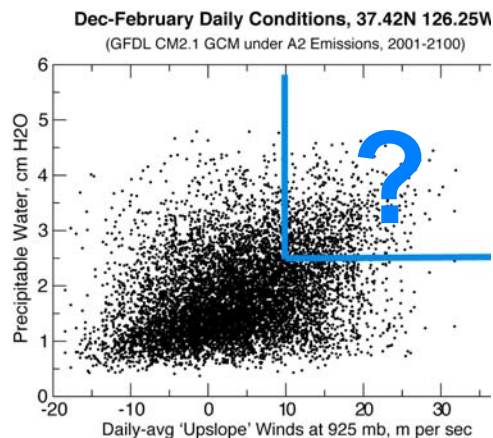


- *Floods on American River assoc with ARs are 10* larger than other flood counterparts (Dettinger 2004)*

How often are historical extreme-precip conditions realized per winter as the climate-change projection progresses?

Numbers of DJF Days in Extreme-Precip Quadrant

(GFDL CM2.1 GCM under A2 Emissions, 2002-2100)



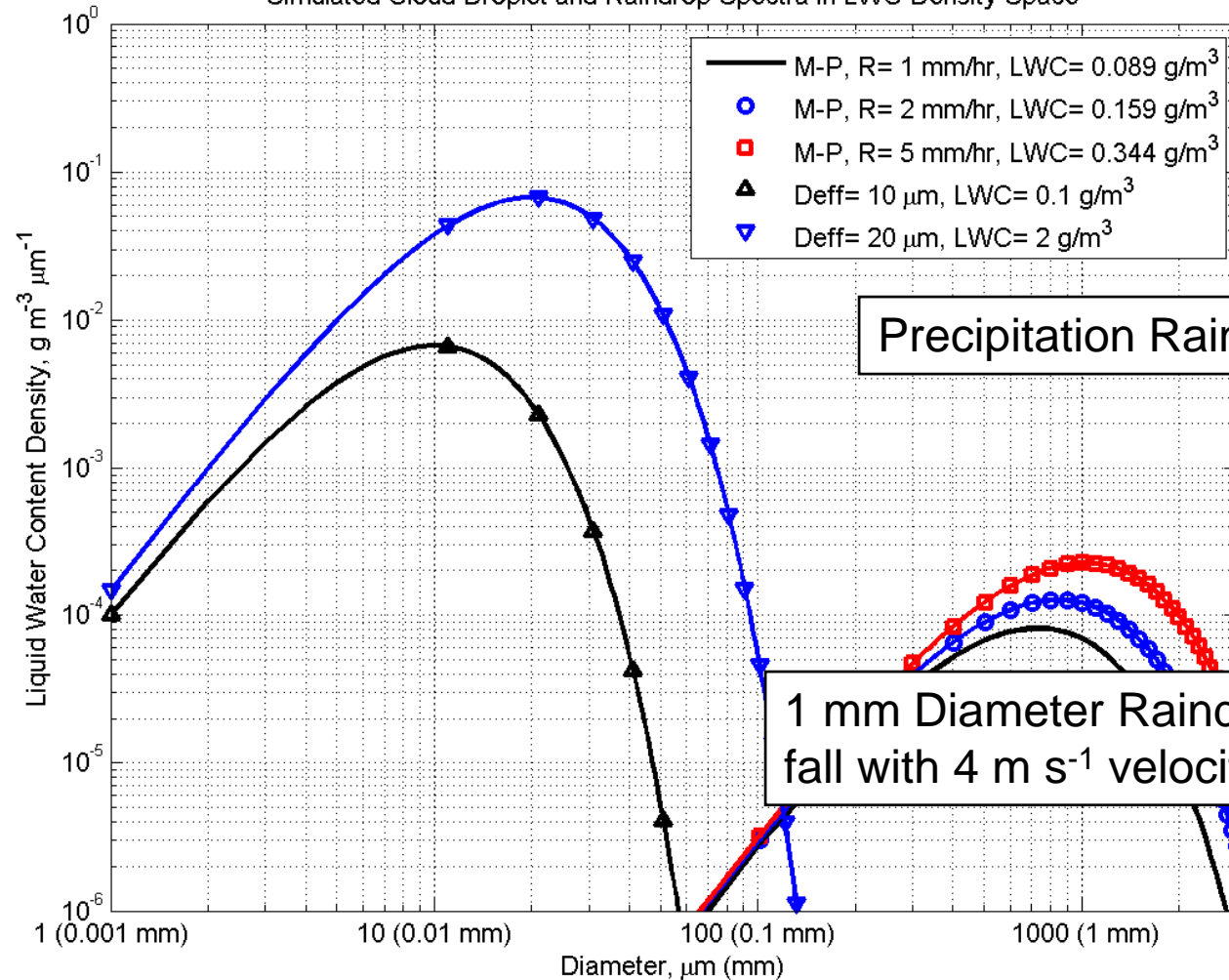
A 50% increase in number of "flood-worthy" storms, i.e., atmospheric rivers?

Aerosols and Precipitation

- Scientific controversy exists regarding the role of anthropogenic aerosols on precipitation efficiency
- Differences center on how changes in cloud droplet distributions affect precipitation efficiency
- Recent advances in measuring and understanding precipitation processes in California are being brought together in CalWater with advances in aerosol measurements and modeling

Cloud Droplets

Simulated Cloud Droplet and Raindrop Spectra in LWC Density Space



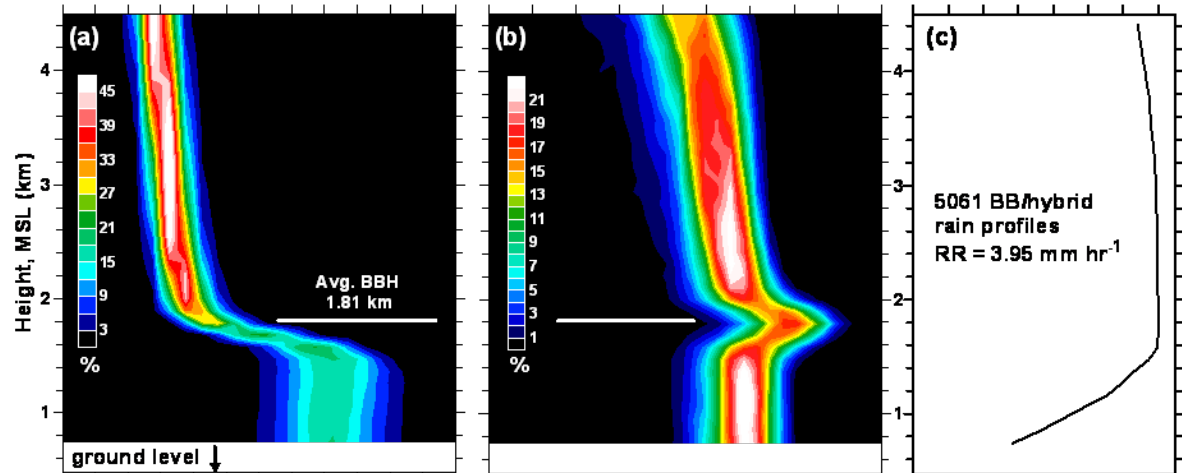
Precipitation Raindrops

1 mm Diameter Raindrops
fall with 4 m s⁻¹ velocities

Vertical Profile of reflectivity and Doppler velocity During Brightband (BB) and non-Brightband (NBB) Rain

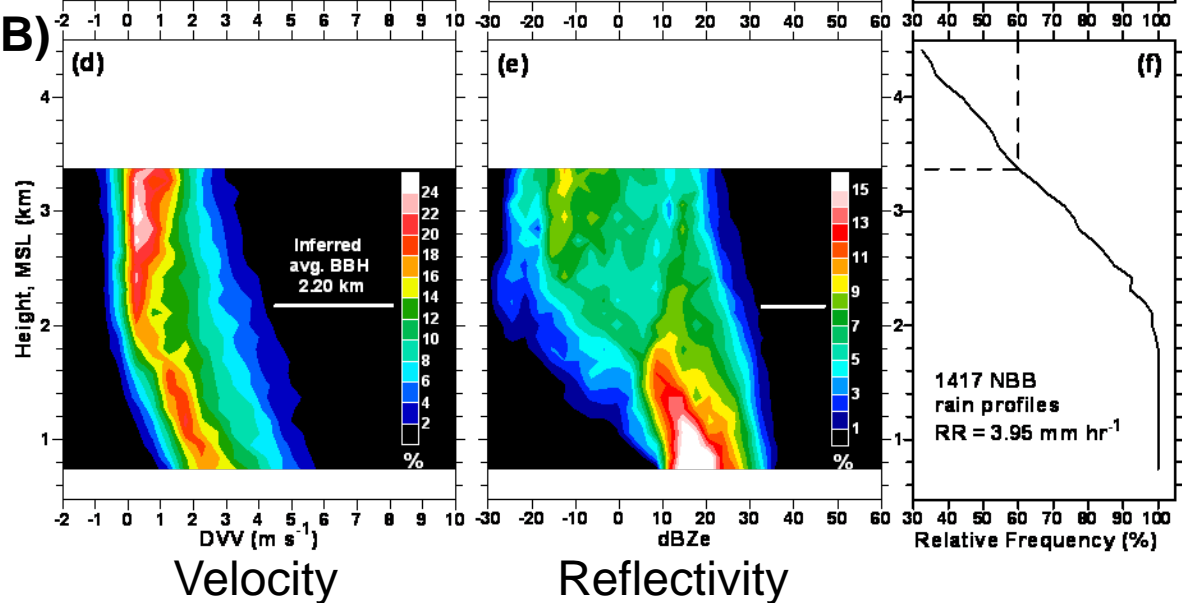
- S-band vertically pointing profiler at Cazadaro, CA

Brightband (BB) Rain (Top Panel)



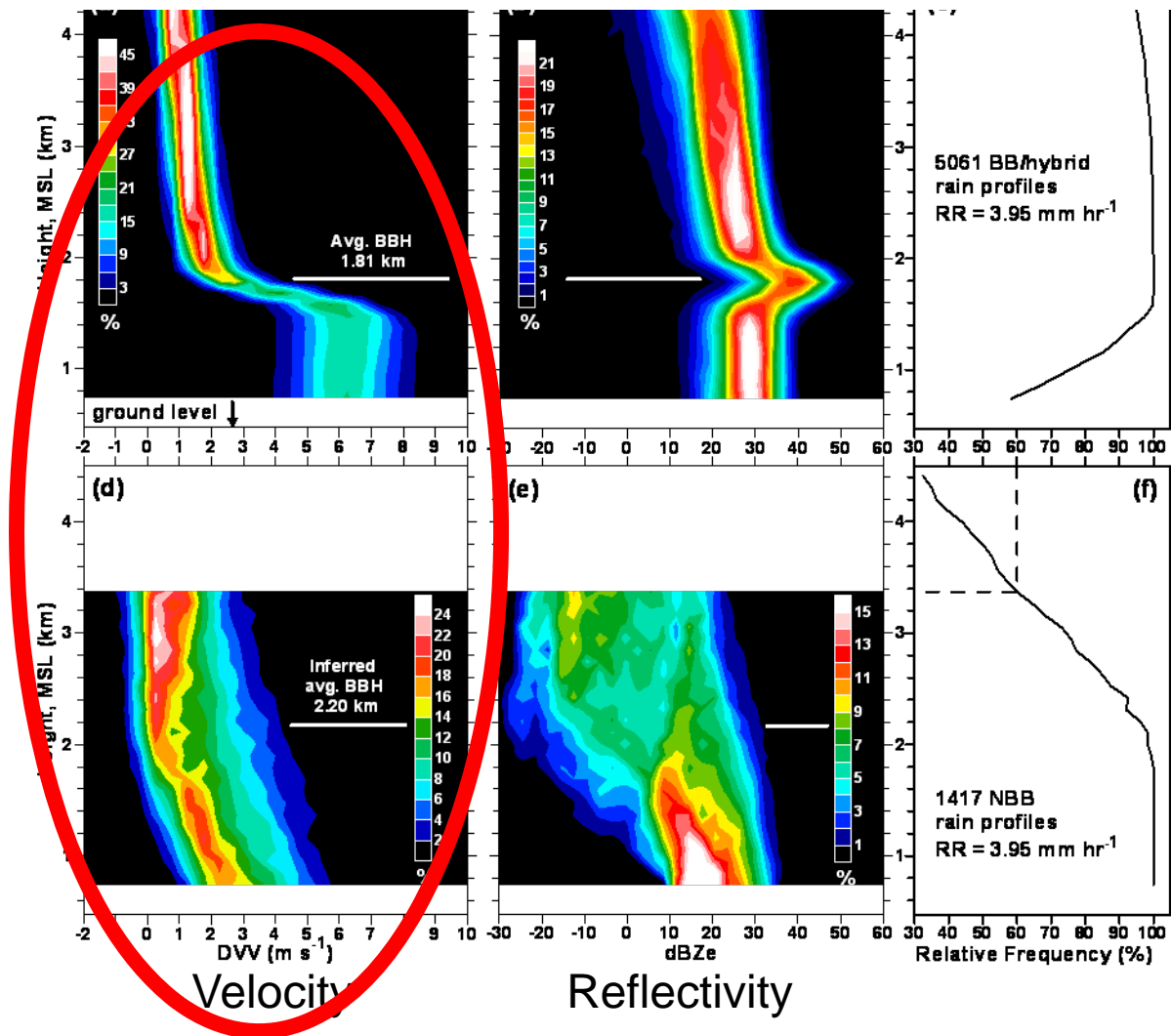
Non- Brightband Rain (NBB) (Bottom Panel)

- All profiles have about 4 mm hr⁻¹ rain rate at surface.
- Different vertical structure of reflectivity is dependent on rain regime.



From White et al. (2003)

New Radar technique identified natural rainfall process involving very small raindrops that produces 25-50% of annual rainfall in CA coastal mountains



From White et al. (2003)

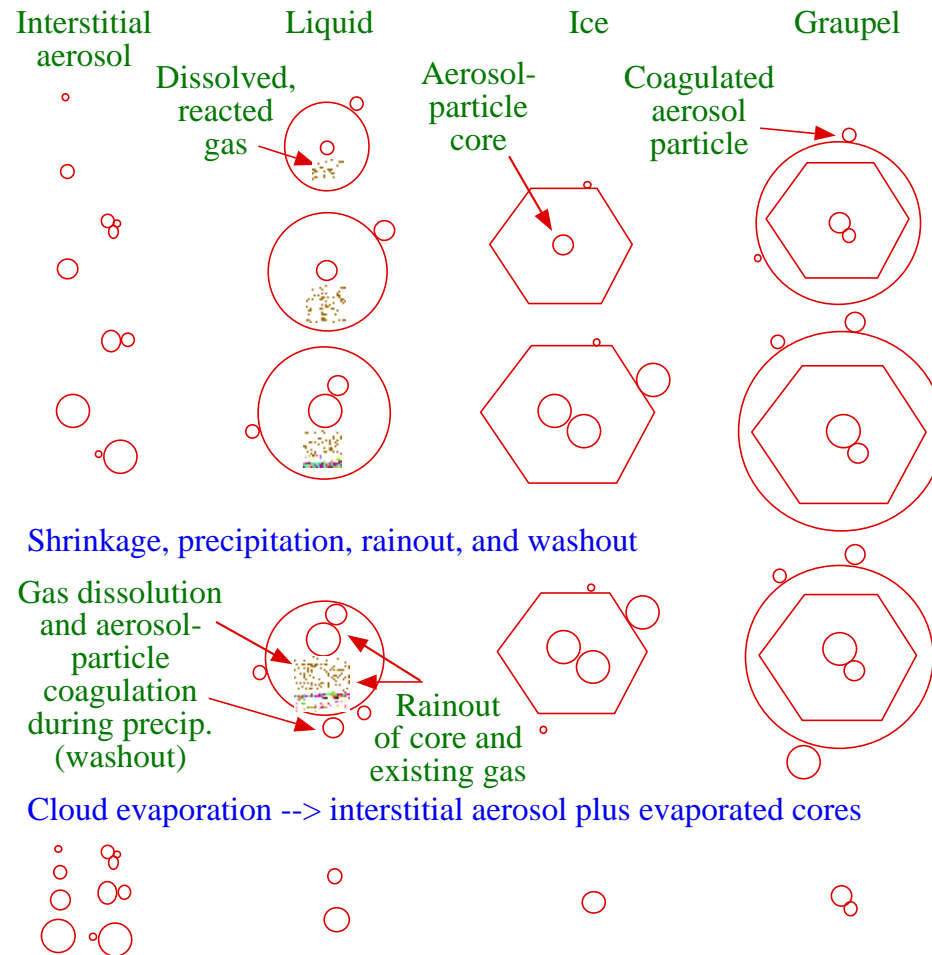
Recent Modeling studies have included complex aerosol processes (Jacobson and Kaufman)

Cloud Microphysical and Chemical Processes

Condensation/deposition of water vapor onto aerosol particles

Coagulation: Aerosol-aerosol Aerosol-liquid Aerosol-ice Aerosol-graupel
Liquid-liquid Liquid-ice Liquid-graupel Ice-ice
Ice-graupel Graupel-graupel

Gas dissolution, aqueous chemistry, hom.-het. freezing, contact freezing



Implications for Rainfall from Jacobson and Kaufman studies

Rainfall in California: 193 million acre-feet/year (1.54 mm/day)

Flow to reservoirs (agriculture/cities/industry): 12.9% (24.9 maf/yr)

Precipitation reduction due to AAPPG: 2-5%

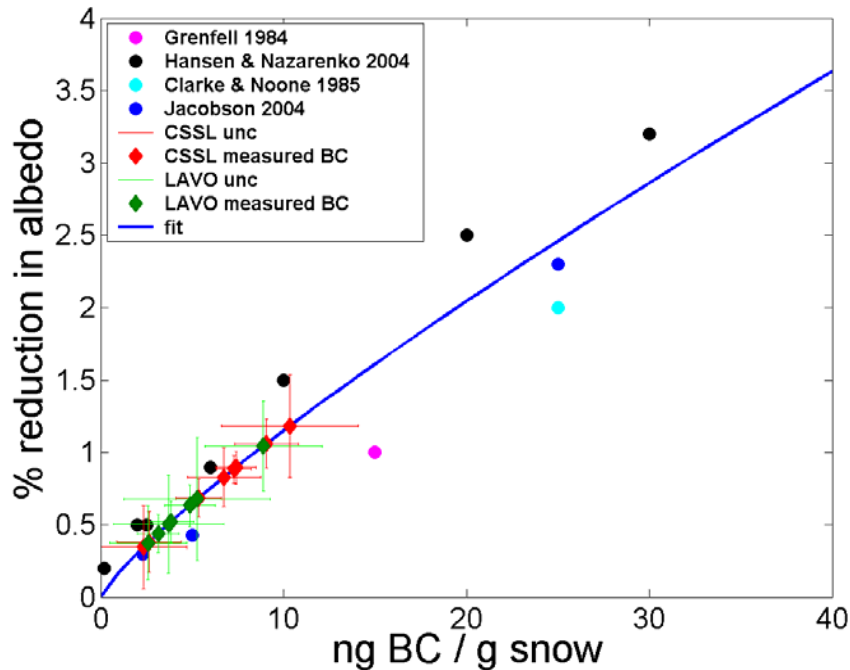
→ Runoff loss to reservoirs: 0.5-1.25 maf/yr

Reducing aerosol pollution could have nearly a similar effect as proposed addition of upper San Joaquin River dam (1.3 maf)

Reducing aerosol pollution could also reduce 4-6 maf/yr needed to meet growth of California 2010 population to 40 million

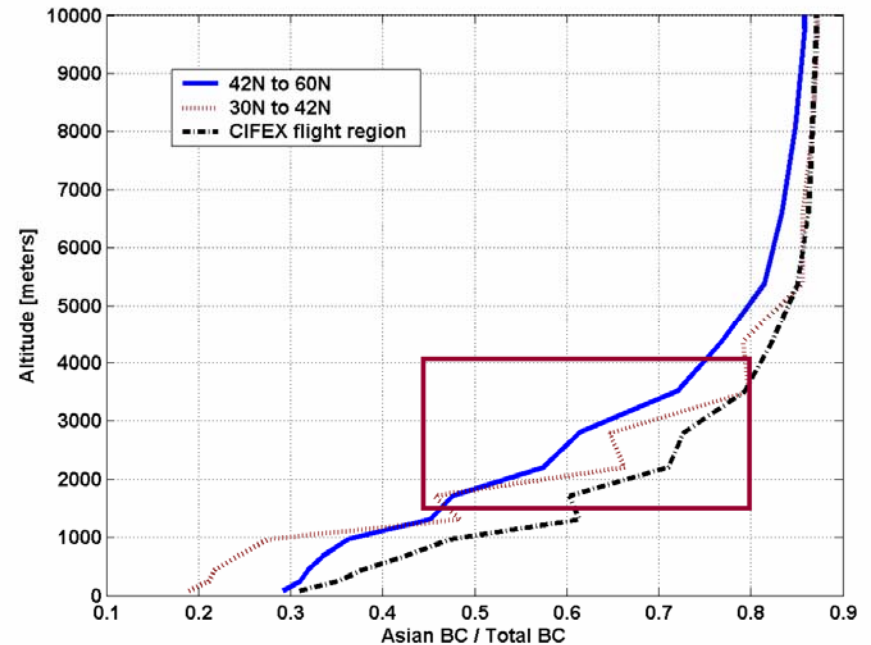
Black Carbon Deposition on Snow

BC reduces albedo - speeds melt



The affect of measured BC concentration in snow at Mt. Lassen Volcano National Park (red) and at Central Sierra Snow Laboratory (green) on snow albedo as predicted by models.

BC from Asia likely contributes

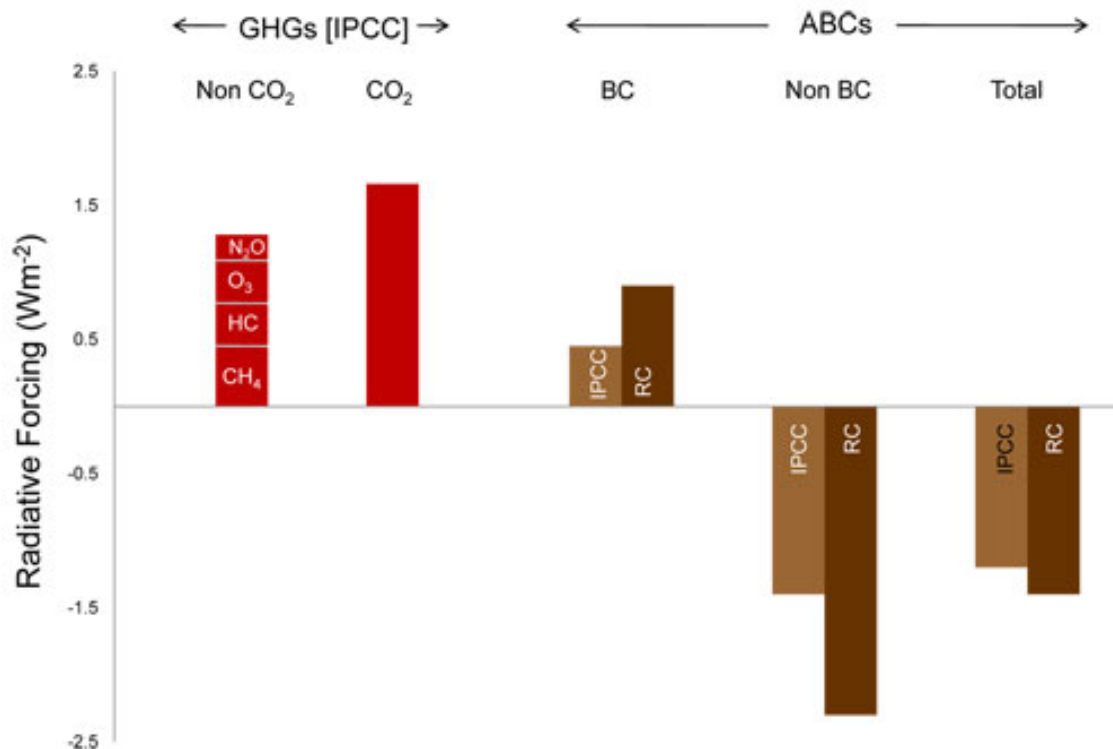


Modeled fraction of Asian BC relative to total BC for three regions in North America. The red box indicates the elevation of California's snow pack.

Courtesy of Hadley, Ramanathan and Corrigan

Black Carbon Radiative Effects

BC has a larger radiative effect than IPCC reports indicated



Global Radiative Forcing estimates by IPCC and by the present study: RC stands for Ramanathan and Carmichael (Nature, 2008). Source: Ramanathan and Feng, In Press, PNAS, 2008.

Courtesy of Ramanathan, Menon and Leung

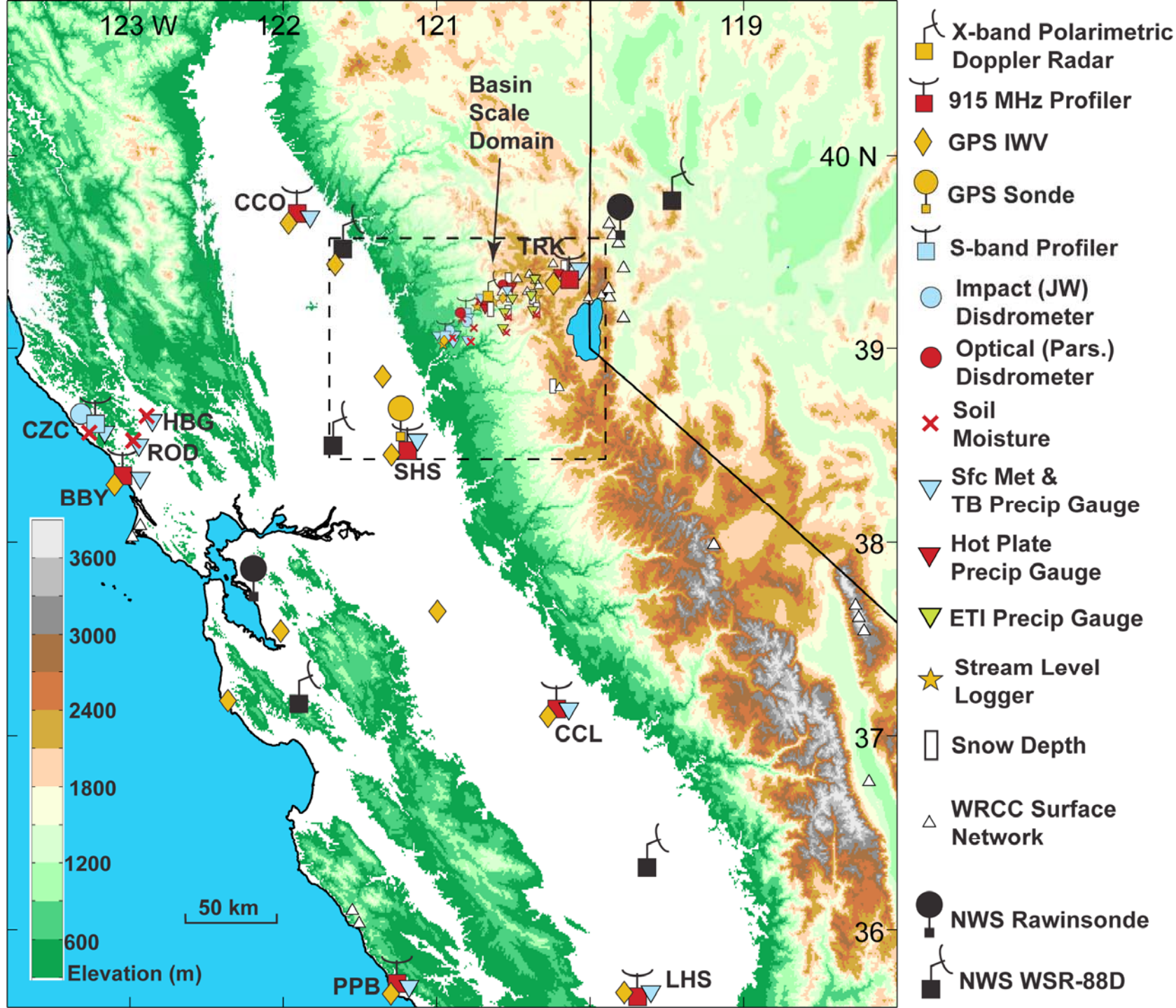
Specific CalWater Science Themes Identified to Address Uncertainties

- Reducing uncertainties in the impacts of anthropogenic aerosols on precipitation – modeling and observational dimensions (e.g., Jacobson, Rosenfeld)
- Long-range black carbon transport and deposition onto snow (e.g., Ramanathan and Hadley)
- The role of shallow rain processes in modulating aerosol impacts on precipitation and on deposition of black carbon (e.g., Williams and White)
- Understanding the role of atmospheric rivers on black carbon transport, aerosol entrainment and precipitation formation, for both water supply and extreme events (e.g., Neiman, Dettinger, Wick)

Experimental Design Leverages Major Projects Already Underway

- CARB Boundary layer monitoring system
- NOAA's Hydrometeorological Testbed (HMT)
- NOAA's Unmanned Aircraft Systems (UAS) Project
- CEC Aerosol Observation Studies (e.g., UAS)

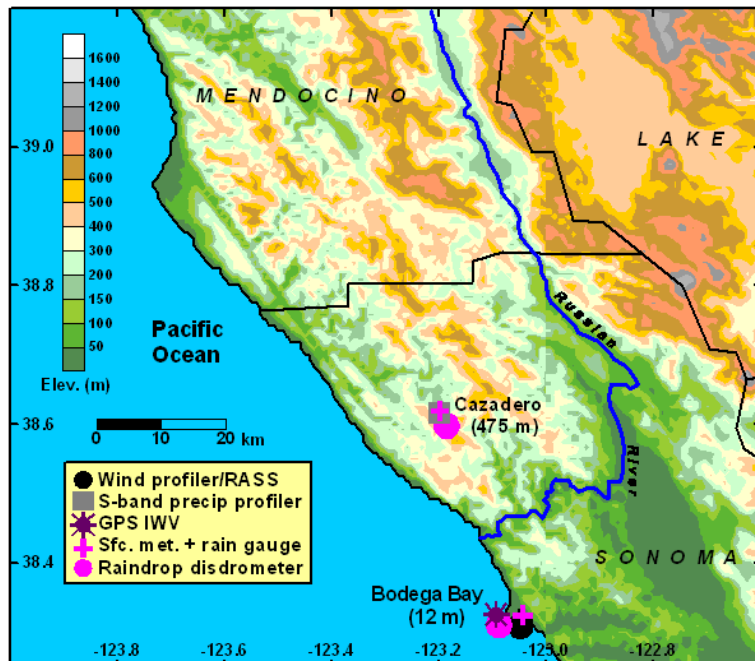
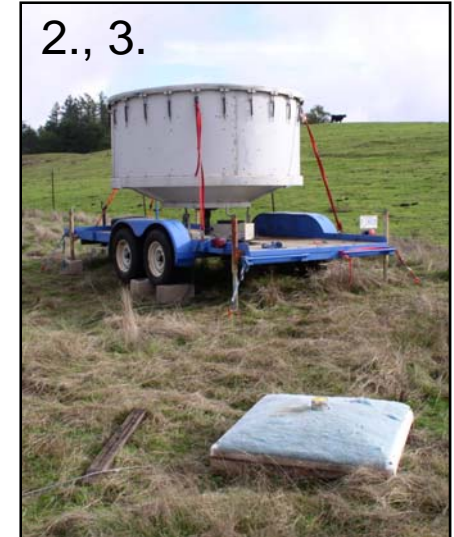
HMT-West 2010 Regional Scale Map



HMT Brings Many ground-based sensors

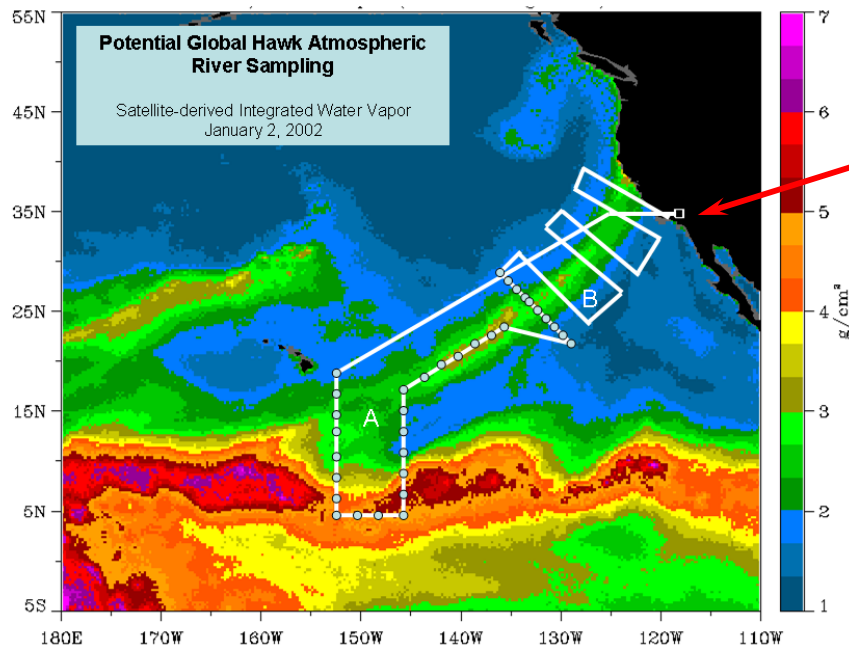
Observing systems:

1. Wind profiler/RASS
2. S-band radar
3. Disdrometer
4. Surface met
5. GPS-IWV
6. Rain gauges



Unmanned Aircraft Systems (UAS) Tests that can Support CalWater Atmospheric River and Aerosol Studies

- Enhanced atmospheric profile, air-sea flux and aerosol observations to improve winter storm forecasts on the west coast
- Potential to combine observations for California water resources and atmospheric river studies using Global Hawk and Manta UAS
- Testing targeted for Summer 2009, mission goal of Winter 09-10
- Measurements from dropsondes and, if available, a wind profiling lidar



Summary

- CalWater is addressing water resources uncertainties by bringing together
 - NOAA, CEC, Other Agency and University
 - Scientists and Resources
- A Science Planning Workshop is being held from 15-17 September to refine plans
- Coordination between CalWater and CalNex will likely center on aerosol measurements and impacts, as well as on use of special meteorological observations

Punch Line

“Water is the next oil.”*

*Venture capitalists and Department of Homeland Security

CalWater Addresses

***Key Uncertainties in Climate Projections
of Water Resources for California – both
for **Water Supply** and
Flooding***

Organizers/Contacts

- Guido Franco: CEC
- Dan Cayan: Scripps
- Marty Ralph: NOAA